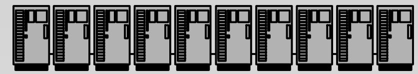
ITR: "Non-Equilibrium Surface Growth and the Scalability of Parallel Discrete-Event Simulations for Large Asynchronous Systems", DMR Award#0113049

Gyorgy Korniss (Rensselaer Polytechnic Institute), Mark Novotny (Mississippi State University)

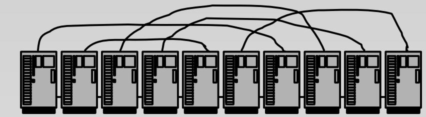
Parallel discrete-event simulation is an invaluable general tool to investigate the dynamic behavior of complex systems. Such systems include battle-field models, models for the spread of diseases and epidemics, cell-phone communication networks, dynamics of materials, and financial markets - some of these being dauntingly relevant in our everyday life.

As tomorrow's state-of-the-art massively parallel architectures will have about a million CPUs (e.g., IBM's Blue Gene Project), the design of scalable algorithms becomes an extremely challenging task. In particular, synchronizing that number of CPUs using some kind of central control is beyond hope.

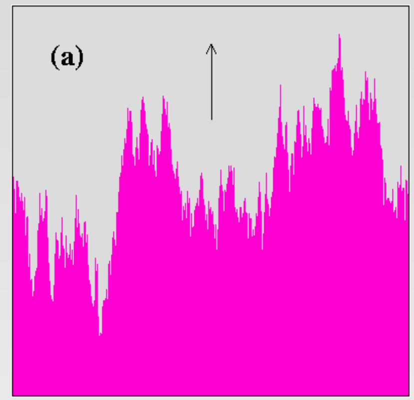
We constructed a novel synchronization protocol in which CPUs operate *autonomously* without any centralized control. We achieved this by requiring each CPU to communicate only with a few others through a *"small-world" network*. This type of complex network (producing the "six degrees of separation") is well known from social systems to be capable of facilitating the spread of information in a highly efficient manner. Providing a near-uniform progress of the CPUs, this method is scalable in both the simulation and the data collection phases of the algorithm. G.Korniss et al., *Science* **299**, p. 677 (2003)



regular one-dimensional communication topology



"small-world" topology when random links are added



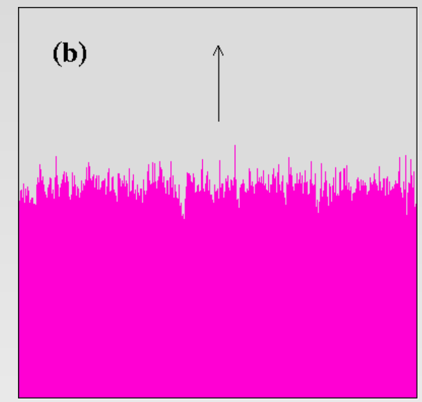


Figure 1 [Horizontal axis: individual CPUs; vertical axis: progress of the simulation of the individual CPUs.] **(a)** When compute nodes only communicate with local neighbors, the spread of the progress of the simulation increases with the number of nodes, making continuous data retrieval not scalable. This corresponds to a wildly fluctuating simulated time horizon (large spread of the progress of the individual CPUs). **(b)** When each node is also required to communicate with a randomly chosen one (resembling a *"small-world" network*), *synchronization emerges spontaneously*, without a central command.

ITR: "Non-Equilibrium Surface Growth and the Scalability of Parallel Discrete-Event Simulations for Large Asynchronous Systems", DMR Award#0113049

Gyorgy Korniss (Rensselaer Polytechnic Institute), Mark Novotny (Mississippi State University)

Outreach activities:
'Questar III New Visions program at Rensselaer: G. Korniss developed lectures for local high-school students to introduce them to basic concepts of simulations and modeling (Spring 2002). In this program, spanning through the full year, high-school seniors (from around the Albany, NY region) can explore basic concepts in science (and other areas as well), e.g., through guest speakers, mentoring, and a senior project.

Educational:
5 undergraduates: Katie Barbieri, John Marsh, Brad McAdam (Rensselaer), Shannon Wheeler, James Nail (MSU); 5 grad students: Hasan Guclu, Balazs Kozma (Rensselaer), Daniel Logue, Poonam Verma,Terrance Dubreus (MSU);
1 post-doc: Alice Kolakowska (MSU);
pre-college teacher: Tammie Borland (Questar III)

Collaborators:
Zoltán Toroczkai (Los Alamos), Per Arne Rikvold, (Florida State University), Zoltán Rácz, (Eötvös University, Budapest), Boris Lubachevsky (formerly at Bell Labs/Lucent)

Figure 2. REU students at Rensselaer, June 2002.

Brad McAdam (middle row, second from the right) is an undergraduate student working with G. Korniss (middle row, first from the right) to study optimal network formation in dynamic agent-based systems. Following his REU experience, he is now a regular semester undergraduate research assistant.